Patient Comorbidities Increase Postoperative Resource Utilization After Laparoscopic and Open Cholecystectomy

Abstract

BACKGROUND: An understanding of the relationship between patient factors and healthcare resource utilization represents a major point of interest for optimizing clinical care and overall net savings, yet maintaining financial margins for provider revenues. This study aims to review resource utilization after cholecystectomy in order to characterize patient factors associated with increased postoperative ED visits and 30-day readmissions.

METHODS: 53,632 open and laparoscopic cholecystectomies were reviewed from July-2009 to December-2010 in a large private payer claims database. ICD-9 and CPT codes were available for each event, as well as basic demographics. Data regarding 30-day postoperative resource utilization metrics (emergency department visits and inpatient hospitalizations) were analyzed and stratified by key patient comorbidities. Differences between subgroups were evaluated with univariate and multivariable methods.

RESULTS: Of the 53,632 patients studied, 71.2% (38,171) were female and 28.8% (15,461) male. Resource utilization within 30-days of surgery included: 6.6% (3,538) of patients with an ED visit and 7.7% (4,103) with an inpatient hospitalization. The most common comorbidities in the study population were: hypertension, hyperlipidemia, GERD / hiatal hernia, and diabetes mellitus. Patients with heart failure, cirrhosis, and a history of MI or acute ischemic heart disease all had a significant association with postoperative ED visit and the highest likelihood of inpatient hospitalization. Angina, diabetes, and hypertension similarly increased both ED utilization and inpatient readmissions to a lesser but still significant extent. Although patients with GERD / hiatal hernia and sleep apnea had a significant association with ED use, they did not have an increased likelihood of readmission.

CONCLUSIONS: Patient comorbidity indexing plays a major role in clinical risk stratification and resource utilization for cholecystectomy. These factors should be considered in bundled reimbursement packages and in the creation of preventive postoperative ambulatory strategies given their role in determining potential resource utilization in the postoperative setting.

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GLOSSARY

ACA	Affordable Care Act
ACO	Accountable care organizations
BPCI	Bundled Payments for Care Improvement
CCTP	Community-based Care Transitions Program
CMS	Centers for Medicare & Medicaid Services
CPT	Current Procedural Terminology
ED	Emergency department
GDP	Gross domestic product
GERD	Gastroesophageal reflux disease
HIV/AIDS	Human immunodeficiency virus / Acquired immunodeficiency syndrome
ICD-9	International Classification of Diseases, Ninth Revision
IHD	Ischemic heart disease
IRB	Institutional review board
JSH	Joint replacement surgical home
LOS	Length of stay
MI	Myocardial infarction
MS-DRG	Medicare Severity Diagnosis Related Group
NOS	Not otherwise specified
OECD	Organisation for Economic Co-operation and Development
OR	Odds ratio
RUQ	Right upper quadrant
THA	Total hip arthroplasty
TKA	Total knee arthroplasty
UC	University of California
VNA	Visiting Nurse Association
VBP	Hospital Value-Based Purchasing Program
WWII	World War II

INTRODUCTION

BACKGROUND: THE US OUTLIER AND THE AFFORDABLE CARE ACT

In mid-2007, the United States began to slip into the start of what was to become the worst financial crisis in the post World War II (WWII) era[1]; it was informally referred to as the *Great Recession.* The US gross domestic product (GDP) dropped a staggering 5.1% during the worst of it, from the fourth quarter of 2007 through the second quarter of 2009. Prior to this, the largest recorded drop in the post-WWII era had been just 3.7% in 1957-1958[2]. Unemployment figures skyrocketed reflecting the 8.7-million jobs lost. Consumer spending and business investments plummeted as the US economy headed towards its worst nadir in modern history[2,3].

Despite the recession and accompanying period of sluggish economic recovery through 2013, the United States spent an estimated $2-3 trillion per year on health care, with expenditures rising annually. Through 2013, health care comprised an impressive 17.4% of the United States GDP[4,5]. This figure corroborates that the US spent more of its GDP on health care than any other country in the world. As evident in **Figure 1** from Schoen et al[6], the US devoted a 6% greater share of its economy on health than the Netherlands, the country with the second largest proportion of its GDP spent on health care.

Were health accessibility, affordability, and outcomes similar between the US and the other countries listed above, perhaps this number would not be so troubling; existing data, however, show that these exorbitant costs did not and still do not translate to better care.

Accessibility

Before the implementation of the Patient Protection and Affordable Care Act (ACA), 16% of the entire US population – consisting of approximately 50-million people – were completely uninsured. Moreover, millions of Americans remained underinsured, meaning they lost a significant portion of their income to health care costs not covered by insurance[6,7]. In some states such as Nevada and Texas, the percentage of uninsured soared at an incredible 27% of the adult population[8]. This remains a stark contrast to the universal health coverage provided by our western counterparts in Europe, where the percentage of uninsured is virtually 0%. **Figure 2** from the Organisation for Economic Co-operation and Development (OECD)'s health indicators[9] depicts the percentages of the population that were either insured (via public or private insurance) or uninsured across the various OECD participating countries in 2007.

Affordability

In the *Schoen et al* study[6] previously mentioned that included ten of the world's major developed nations in addition to the US, adults in the US were more likely than adults in any other nation to have healthcare access issues related to cost. For example, they were the most likely to have not seen a doctor when ill or not get recommended care due to cost. They also did not fill their prescription medications and skipped medication doses 2.6 times as often as adults in the country second most likely to have done so, Canada. Finally, adults in the United States were more likely than adults in all other countries to have had $1,000 or more out-of-pocket medical expenditures.

Health Outcomes

Life expectancy and child mortality: In 2007, life expectancy at birth in the US (78.1 years) was one year less than the OECD average (79.1 years) and approximately two years less than that of any western European nation. Although life expectancy in the US (78.8 years) increased slightly in 2013, it staggered and lingered almost one year behind the OECD average (80.5 years) and 2-4 years behind the life expectancy in western European nations[9,10].

Low birth weight: The US had one of the incidence levels of low birth weight infants in 2007, with 8.3% of infants born weighing less than 2,500g; the OECD average at the time was 6.8% of infants. Both incidence levels decreased in 2013, with the US at 8.0% of infants weighing less than 2,500g at birth and the OECD average at 6.6% of infants[9,10].

Prevalence and incidence of various illnesses: The estimated prevalence of diabetes in the US (10.3%) ranked only second to Mexico (10.8%) in 2010, and led the OECD average

(6.3%) by a full four percentage points. In 2006, the incidence of HIV/AIDS was highest in the US of all the OECD countries, at a stunning 127 new cases per million in the general population; OECD average was almost eight times less, at 16.2 new cases per million[9,10].

Mortality due to various illnesses: As compared to other western European nations, the US ranks highly in terms of death as a result of ischemic heart disease (IHD) although this number has decreased since 2006. Mortality rates due to all cancers and cerebrovascular disease were appreciably lower in the US than in other western nations in both the OECD's 2009 and 2015 reports[9,10].

Defining Value

Figure 3 depicts the relationship between life expectancy and total health spending per person[11]. The United States is shown on the far right-bottom with a high cost and low life expectancy, relative to the other countries shown. Similarly, **Figure 4** demonstrates the association between child mortality and total health spending per person[11]. The US is shown on the far right-top with a high cost and high child mortality. Michael Porter from Harvard Business School defined *value* within health care delivery as the health outcomes achieved per dollar spent[12]. Given the low life expectancy and high child mortality rates despite the elevated cost of care, these data indicate that the value of health care in the US is inferior to that of much of the developed world.

In order to begin to address these overwhelming issues of poor access to health, inadequate insurance coverage, unsustainable costs, and the inferior value of health care in the US, the ACA was implemented in 2010[13]. The ACA created the structural foundation for interventions intended to increase insurability and contain healthcare costs. Examples of cost-containment programs included in the act were Community-based Care Transitions Program (CCTP) to decrease readmission rates, Hospital Value-Based Purchasing Program (VBP) to shift financial risk from Medicare to providers in order to transform incentives, and the Shared Savings Program to reward providers for reducing costs[7]. The scaffolding that the ACA provided laid the groundwork for the establishment of accountable care organizations (ACOs) and the widespread use of bundled payments. In 2011, the Centers for Medicare & Medicaid Services (CMS) launched the Bundled Payments for Care Improvement (BPCI) initiative in accordance with Section 3023 of the ACA; this stated that Medicare bundled payments would be piloted in 2013. CMS commenced the application of cost savings paradigms via bundled payments when it announced the healthcare organizations selected to participate as ACOs in the BPCI in January of 2013[14]. Through these approaches, implementation of the ACA has slowly initiated a transformation in economic incentives that increase provider participation in order to achieve its goals of creating high value, affordable health care available to most[15]. Thus, the ACA triggered a closer look at healthcare spending with the aim to decrease inefficiencies, increase the quality of care that patients receive, and lower overall healthcare costs.

Risk Stratification of Bundled Payments

In order to account for fluctuations in costs per patient, the ACA called for a risk adjustment strategy. Accordingly, bundled payments in the ACA and BPCI initiative were founded in risk stratification based on the existing Medicare Severity Diagnosis Related Group (MS-DRG). The MS-DRG attaches significance to acute illnesses or acute decompensations of chronic illnesses[16]. Thence, bundled payments to ACOs were to include increased payments based on MS-DRG risk stratification to to compensate for the higher costs of treating more severely ill patients.

The higher cost of treating sicker patients does not solely correlate with the acute disease burden represented by the MS-DRG, however; chronic disease burden significantly impacts a patient's total cost of care and may in fact play a greater role in resource utilization than acute disease burden does. Vertrees et al found that a patient's chronic disease burden may in fact be more predictive of a patient's resource use than the acute disease burden[16]. Hughes et al showed the predictive power of integrating the chronic disease burden of patient comorbidities into a system of risk categories in order to stratify patients by their expected use of healthcare resources in a future year[17]. Therefore, although existing risk adjustment under the ACA was founded in the known effects of acute illness, chronic disease burden may also prove a significant target.

Case: The Cholecystectomy and Contributors to Resource Use

Gallstone disease is the fourth most costly gastrointestinal disease in the United States; direct and indirect costs for care related to cholelithiasis totaled $6.2-billion in 2004[18]. Not surprisingly, the cholecystectomy is the most common elective abdominal surgical procedure performed in the United States with more than 750,000 cases occurring each year[19]. Considering the factors that contribute to the estimated $15,651 median cost per case[20], complications and comorbidities may play a significant role in the total cost of care. Injury to the common bile duct is well known as a major contributor to cost and resource utilization, with immediate associated costs ranging from $13,612 to $30,000 and lifetime costs reported as high as $300,000[21–24]. In addition, various patient, hospital, and surgeon factors – such as age, sex, presence of comorbidities, urgency of admission and surgery, length of stay (LOS), treatment in a regional or district hospital, hospital volume, and surgeon experience[25–32] – have been shown to affect cholecystectomy outcomes and associated overall resource use and costs.

As previously mentioned, chronic disease burden has been shown to be more predictive of patient cost and resource use than acute illness[16,17]. Prior studies have also evinced the influence of patient comorbidities on the utilization of resources such as office visits, emergency department (ED) visits, length of stay, drug costs, procedures, and overall costs in other study populations[33–37].

Given the significance of chronic illness burden and the knowledge of how patient factors influence resource utilization in other conditions, this study serves to elucidate the impact of specific patient comorbidities on resource utilization after cholecystectomy. In the context of our current healthcare system's movement towards innovative reimbursement models, quantification of these impacts may be useful to payers for guiding the development of risk-stratified, case-mix appropriate bundled reimbursement packages to providers for cholecystectomies. Furthermore, this information may be useful to providers in order to create strategies to prevent excess resource utilization, thereby decreasing inefficiencies, increasing the value of care for patients, and simultaneously creating profit margins under the ACA's Shared Savings Program.

Methods

This was a retrospective observational cohort study of privately insured patients undergoing cholecystectomy in which predictor variables were defined by the presence or absence of various chronic comorbid conditions. Approval from the Cambridge Health Alliance institutional review board (IRB) was obtained.

Study Design

This study was a retrospective cohort study utilizing a private payer claims database (Aetna, Inc., Hartford, CT). Inclusion criteria consisted of age ≥16 years, a record of cholecystectomy between July 1, 2009 and December 31, 2010, and enrollment in the health plan for at least 6 months before and 3 months after the cholecystectomy to stabilize the co-morbidity database and allow tracking of consecutive health events and resource use. Claims records were stripped of protected health information by Aetna personnel not involved in this study to produce the HIPAA-compliant de-identified dataset used in this analysis. Cholecystectomy procedures were identified by the International Classification of Diseases, Ninth Revision (ICD-9) or Current Procedural Terminology (CPT) codes listed in the appendix.

Outcome Measures

Data regarding 30-day postoperative resource utilization were stratified and analyzed by patient comorbidities. The comorbid conditions that were studied include hypertension, hyperlipidemia, gastroesophageal reflux disease (GERD) / hiatal hernia, diabetes mellitus, angina / chronic IHD, sleep apnea, heart failure, myocardial infarction (MI) / acute IHD, hypertensive heart disease, and cirrhosis of the liver or bile ducts. These conditions were defined by the presence of an associated ICD-9 code within the 6-month period immediately prior to the cholecystectomy.

The endpoints in this study were 30-day ED visits, 30-day readmissions, and length of stay for the 30-day readmissions. A readmission was defined as utilization classified as inpatient in the source data. Length of stay was calculated as discharge date minus admission date.

Statistical Analyses

Descriptive statistics were used to summarize baseline patient characteristics, including demographics and comorbid conditions. Outcomes were summarized for the overall population and by subgroups with and without each comorbid condition. Pearson's chi-squared p-values were calculated to evaluate the statistical significance of all differences in outcomes between cohorts. No adjustments were made to these p-values to account for multiple comparisons.

Logistic regression was utilized to determine the impact of baseline comorbid conditions on 30-day readmission rates, while adjusting for demographic differences. Stepwise selection was used to choose the statistically significant predictor variables from among all studied comorbid conditions, age, gender, and region. Sensitivity regression models were also run for the subsets of readmissions including and not including an overnight stay. All statistical analyses were conducted using SAS Version 9.2 (SAS Institute, Cary, North Carolina).

RESULTS

A total of 53,632 patients was included in this study; 71.2% (38,171) were female, 28.8% (15,461) male. Baseline patient characteristics are shown in **Table 1**. Of all cholecystectomies studied, 94.9% (50,900) were laparoscopic, 63.9% (34,285) were outpatient procedures, and 51.2% (27,439) occurred in the South (US Census Region 3) of the United States. The prevalence of chronic comorbidities seen in the study population are reported in **Table 2**. Hypertension, hyperlipidemia, GERD / hiatal hernia, and diabetes mellitus were the most prevalent of the comorbid conditions studied, at 34.2% (18,324), 30.7% (16,436), 25.1% (13,465), and 13.7% (7,354) in the study population, respectively.

Within 30-days of surgery, 6.6% (3,538) of patients returned to the ED a total of 4,523 times. This led to an average of 1.3 ED visits per patient visiting the ED and an average of 0.1 ED visits for the entire cohort. Additionally, 7.7% (4,103) of patients had inpatient readmissions within 30-days of their procedure. Of all patients with 30-day inpatient readmissions, 60.0% (2,461) had a LOS of 0 days[*], 16.5% (677) 1-2 days, 14.2% (583) 3-5 days, 5.2% (214) 6-10 days, and 4.1% (168) 11 days or longer. (**Table 3**) The top three diagnoses recorded during the inpatient readmissions were abdominal pain at an unspecified site, chest pain not otherwise specified (NOS), and abdominal pain in the right upper quadrant (RUQ) at 7.6% (700), 2.4% (223), and 2.4% (217), respectively (**Table 4**).

ED visits were not significantly different across sexes but inpatient hospitalizations were, with males comprising a greater proportion of readmitted patients (9.9% males versus 6.8% females, $p<0.0001$) (**Table 5)**. Resource utilization within 30-days of cholecystectomy, stratified by comorbid conditions, is shown in **Table 6**. All of the comorbidities studied, except for hyperlipidemia and hypertensive heart disease, had a significantly increased postoperative ED utilization.

Odds ratios and 95% Wald confidence limits for the effect of baseline comorbidities on 30-day readmission are shown in **Table 7**. All studied comorbid conditions except GERD and

[*] Lengths of stay were calculated by subtracting discharge date from admission date. LOS of 0-days informs that the admission and discharge date were the same, suggesting discharge from the hospital *before midnight* on the same day as admission.

sleep apnea were statistically significant predictors of 30-day readmission. Of the remaining baseline comorbidities, all resulted in increased risk of readmission except for hyperlipidemia, which showed a slightly reduced risk after adjusting for all other predictors [Odds Ratio (OR)=0.867, CI: 0.801-0.938, p=0.0004]. Comorbid conditions that significantly increased the odds of a 30-day readmission included both acute and chronic IHD, cirrhosis of the liver or bile ducts, diabetes, heart failure, hypertension, and hypertensive heart disease. Age also had a highly significant impact on 30-day readmission, with OR estimates increasing from 0.993 for ages 35-44 to 4.277 for ages 75 and older. Gender and region had modest but statistically significant impacts on 30-day readmission, with females at lower risk than males and patients in the South having the lowest regional risk compared to patients in the Midwest with the highest risk of readmission.

Discussion

Interpretation of Results

The relationship between chronic patient comorbidities and postoperative resource use after cholecystectomy has been poorly defined in the literature. Some reports relating comorbidities and/or complications to cost exist[20,21,25,26], but a greater understanding of chronic disease burden on the utilization of specific resources is needed to guide both economic policy and clinical decision-making. This paper is intended to define the relationship that exists between patient comorbidities and postoperative utilization of resources in terms of distinct visits after laparoscopic and open cholecystectomy.

In this study, patients with heart failure were the most likely of all to visit to the ED and to be readmitted; in fact, these patients are 2.1 times more likely than healthy patients to be readmitted within 30-days of their cholecystectomy. Patients with either cirrhosis or a history of acute IHD also had significant association with postoperative ED visit and were 1.5-1.6 times as likely to have an inpatient readmission. Those with chronic IHD, diabetes mellitus, and hypertension had a significant association with ED visit and also had a modestly increased likelihood of inpatient readmission that was 1.2-1.3 times that of their healthy counterparts.

Forty-six percent of cholecystectomy costs are attributable to room and board[20]. Therefore, it is prudent to note the influence of the comorbidities that increase readmission rates and inpatient LOS after cholecystectomy in addition to those that increase ED utilization. Hyperlipidemia did not increase ED utilization and was a negative predictor of inpatient readmissions in this study population. This may reflect a population of otherwise healthy patients presenting with a 'laboratory comorbidity' as defined by strict numbers yet without any type of actual visceral organ disease.

These data demonstrate how two patients with similar costs but different chronic conditions lead to different utilization of resources after surgery: a patient with GERD who visits the ED repeatedly for reflux symptoms and pain in the postoperative setting versus a patient with cirrhosis and heart failure requiring a prolonged inpatient hospitalization postoperatively due to fluid shifts and heart failure exacerbation after intraoperative fluid resuscitation. Although these patients may be very similar in a strictly monetary sense, their use of hospital resources is vastly different. These insights will prove extremely valuable for applying paradigms for care coordination and cost savings under the ACA.

Relevance to Payers

An understanding of the specifics of resource utilization by patient comorbidity will first allow for appropriate departmental reimbursements by insurance companies. In this analysis, not every comorbidity that increased utilization of ED resources led to increased readmission rates. The two comorbidities that were associated with an increased likelihood of ED visit that did not lead to inpatient readmissions were GERD / hiatal hernia and sleep apnea. Similarly, the impact of resource use will vary from organization to organization based upon the characteristics of their patient population.

Second, an understanding of the impact of each comorbidity from this paper can form the foundation for the risk adjustment of bundled payments for cholecystectomies based on a particular healthcare system's chronic illness trends in their patient population. Calculations for bundled payments would be based on the likelihood of the various types of visits and LOS for inpatient readmissions.

Relevance to Providers and Hospital Administrators

Past successes in bundled payment models exist, a prime example of which is Geisinger Health System's ProvenCare initiative for coronary artery bypass grafting[38]. However, reimbursements for surgical procedures are decreasing in the face of increasing productivity and governmental regulations. Over the past 15 years, reimbursement has decreased by 2.9% for cholecystectomies[39]. At present-day Medicaid reimbursement rates, Frazee et al's analysis[40] defines the 'break-even point' for laparoscopic cholecystectomy at 454 cases - this presents a major financial limitation to lower-volume centers performing this operation and therefore may negatively impact access to care. Analysis of the comorbid conditions in a particular healthcare group's coverage will aid in the projection of resource utilization and subsequent administrative planning for cholecystectomy. Such preparation will enable various processes: Opportunities for the creation of preventive strategies, optimization of healthcare delivery, and appropriate distribution of reimbursement profiles to enable increased profit margins for providers, in the context of the risk-adjusted reimbursements from payers mentioned above.

From the clinician perspective, the knowledge gained from this study will be used to guide strategies to optimize patients in the perioperative period and consequently, decrease postoperative resource utilization. Strategically preventing exacerbation of existing patient comorbidities in the perioperative setting represents one of the major goals of the BPCI and is currently a hot topic in the surgical care realm. To undertake this daunting task, administrators, physicians, and ancillary staff have come together in the few years since the implementation of the ACA to create the perioperative surgical home (PSH) model of care[41].

A mélange of evidence-based practices from lean six sigma theory and its predecessor, Enhanced Recovery After Surgery (ERAS)[41], the PSH model of care has already been shown to minimize postoperative resource utilization and costs. In 2012, University of California (UC) Irvine implemented the patient-centered and physician-driven PSH model of care when it initiated its total knee arthroplasty (TKA) and total hip arthroplasty (THA) programs; a follow-up study in two years after the commencement of both programs compared its costs to those in the reported literature. Costs for UC Irvine’s TKAs were, on average, $6,000-$8,000 less than the benchmark comparison[42] and its THAs were approximately $5,000-$8,000 less[43].

Under the PSH model of care, interventions are targeted at various levels of patient care – the preoperative, intraoperative, and postoperative periods[41]. Innovative examples of cost saving strategies specific to patient comorbidities at each level of care might include the following.

Preoperative Period

Physicians could coordinate close follow-up in the 1-2 weeks prior to surgery for patients most likely to be readmitted. Such care could include weekly in-office visits or frequent phone calls with ancillary medical staff for careful titration of medications aimed at optimizing the patient’s physiologic balance before surgery.

Intraoperative Period

During the intraoperative period, anesthesiologists must maintain equilibrium despite often opposing physiologic and surgical needs, with the added burden of chronic illness. If a patient is afflicted with a comorbid condition that significantly increases their likelihood of readmission such as heart failure in this study's dataset, the anesthesiologist could consider immediate preoperative evaluation in the holding area with a bedside pulmonary and/or transthoracic ultrasound. This cheap and quick bedside examination could provide valuable information regarding the patient's cardiac function and overall volume status via the presence of pathology such as pulmonary edema, pleural effusions, and inferior vena cava variability[44]. The anesthesiologist could then use this information to guide a restrictive or liberal volume resuscitation protocol intraoperatively, depending on other surgical factors as well.

Postoperative Period

In addition to the existing foundations for surgical recovery laid out by ERAS, clinicians could coordinate close follow-up care targeted at preventing exacerbations of chronic conditions for the patients statistically most likely to return to the hospital based on their disease states. Perioperative care physicians could coordinate follow-up telephone calls, home ambulatory services such as Visiting Nurse Association (VNA) visits, and outpatient follow-up with primary care providers. Without the added assurance of in-house hospital monitoring, the postoperative period provides a unique environment in which the use of innovative technology could have great potential. Mobile health technologies could be provided to the highest-risk patients for real-time monitoring by third-party agencies and reporting to ancillary staff for health optimization. This novel application of technology could prevent chronic health exacerbations at the first sign of pathology, before symptoms ever developed and well before patients visited the ED or were readmitted. Devices could include smart watches for heart rate monitoring, at-home scales and sphygmomanometers with real-time data transmission, and more.

These services could not only lead to less ED visits and inpatient hospitalizations, but also result in better coordination of care, create greater value of services received for patients, and yield lower overall costs to the healthcare system. Although a study using aggregates of comorbidity information could have led to similar findings in terms of identifying trends in resource utilization with increasing chronic disease burden, aggregate patient data would not have allowed for the specific information provided by this study's data to create targeted prevention strategies for individual comorbidities.

The knowledge gained from this study can be used to: (1) Influence payers to create evidence-based payment models with global reimbursements focused on clearly defined packages of patient-centered and risk-stratified post-discharge resources in the postoperative setting after cholecystectomy; and (2) Guide providers to create targeted cost saving interventions in the pre-, intra-, and post- operative periods aimed at decreasing resource utilization for patients in the highest risk groups.

Suggestions for Future Work

Although the prevention strategies mentioned are certainly possible for reducing postoperative resource utilization, an understanding of the cause of these readmissions must first be established. Suggestions for future work include root cause analyses to determine the factors contributing to ED visits and readmissions in the postoperative setting for the comorbidities mentioned in this study. Additional work thereafter could include application of tactics targeted at these causes and an analysis of the impact of such interventions.

Limitations

Despite the advantages of using a large private payer database for studying postoperative resource utilization after cholecystectomy, there are several limitations to this approach. The major limitations relate to the use of claims data, namely that we must use ICD-9 diagnosis codes to determine patient comorbid conditions and that the study population is not nationally representative. The data source used in this study only included subscribers to a single private insurance provider and did not include the uninsured population. Using ICD-9 codes to determine comorbidities can lead to under-representation of the conditions in the study population, though coding of chronic conditions tends to be much more complete at the time of hospitalization and/or surgical intervention. Although the comprehensive nature of patient utilization captured in claims data is helpful for elucidating 30-day postoperative resource utilization, it likely overestimates the use of resources associated with cholecystectomy, as the etiology of the visit or hospitalization could be another, unrelated source.

Obesity is known to both correlate with and contribute to the pathophysiology of many of the conditions associated with increased utilization of resources in this study, such as hypertension, hyperlipidemia, GERD and hiatal hernia, diabetes mellitus, heart disease, sleep apnea, and heart failure[45]. The multivariate analyses we conducted allowed for the evaluation of each risk factor independently of the other but did not allow for the evaluation of the effects of obesity, a variable excluded from the study due to severe under-reporting of obesity codes. Martin et al's Canadian study[46] revealed that a diagnosis of obesity had a sensitivity of a mere 7.75% in their database of 17,380 patients; similarly Januel et al[47] show the scanty sensitivity of obesity coding in Switzerland (ranging from 29.4% in 1999 to 51.5% in 2003). These studies convey the extent to which obesity is under-reported in administrative databases. Therefore, it was not possible to determine the resultant effect of obesity on postoperative resource utilization in this study. In accordance with the ACA mandate that healthcare claims data be used extensively to assess resource utilization and quality of care starting in 2015[13], it is inevitable that large payer and other administrative databases will be increasingly used to evaluate healthcare systems in the near future. In order for authorities involved in all aspects of healthcare to draw accurate conclusions from these databases, more precise coding information regarding obesity needs to be included.

Finally, Rao et al demonstrated that dialysis-dependent patients with end-stage renal disease had an increased risk of a number of postoperative complications after laparoscopic cholecystectomy which led to increased mean length of stay in the hospital[48]. Due to the low number of patients with renal failure in the study cohort, however, this condition was not included in the analysis.

CONCLUSIONS

This study showed that certain comorbid conditions significantly increase utilization of postoperative resources in terms of ED visits and inpatient readmissions. In particular, heart failure, cirrhosis, and a history of MI / acute ischemic heart disease were not only significantly associated with increased ED utilization but also had the highest likelihood of inpatient readmission. Further investigation may identify the causality of these relationships and lead to the development of preventive strategies. Such an approach has the potential to not only decrease unnecessary visits, but also improve the quality of patient care and maintain provider profit margins in the face of decreasing reimbursements for surgical procedures. These factors should be considered in bundled reimbursement packages given their role in determining potential resource utilization in the postoperative setting.

A report of this work has been previously published (Boehme et al, 2015)[49].

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Figures and Tables

Figure 1: Profiles of health spending and coverage in eleven countries[6].

	Health spending, 2011		
	Per capita, USD	% GDP	Deductible
United States	$8,508	17.7%	Yes, no limit
Netherlands	$5,099	11.9%	$460
France	$4,118	11.6%	No
Germany	$4,495	11.3%	No
Canada	$4,522	11.2%	No
Switzerland	$5,643	11.0%	$319-2,655
New Zealand	$3,182	10.3%	No
Sweden	$3,925	9.5%	No
United Kingdom	$3,405	9.4%	No
Norway	$5,669	9.3%	No
Australia	$3,800	8.9%	No

Figure 2: Health insurance coverage for a core set of services, 2007[9].

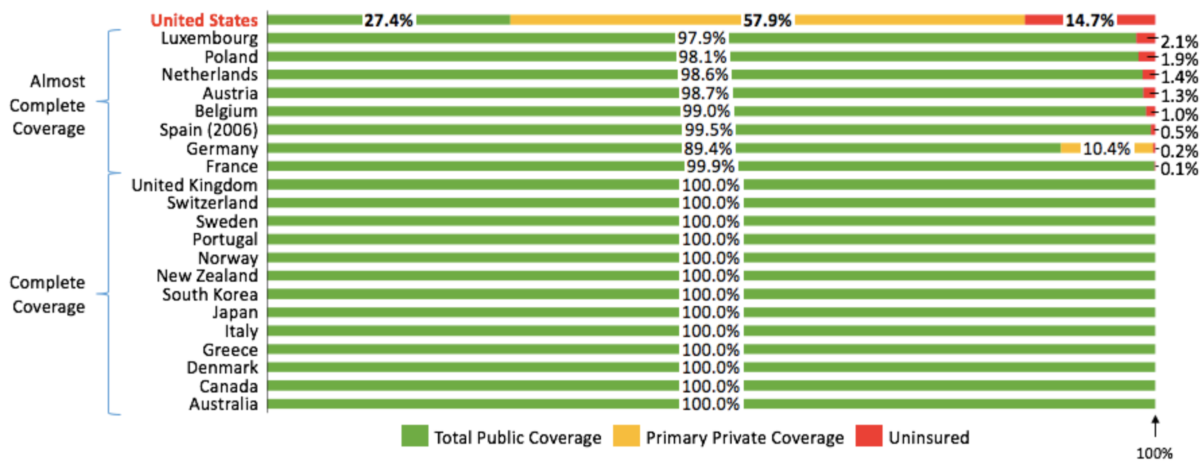

Figure 3: The relationship between life expectancy and health spending per person[11].

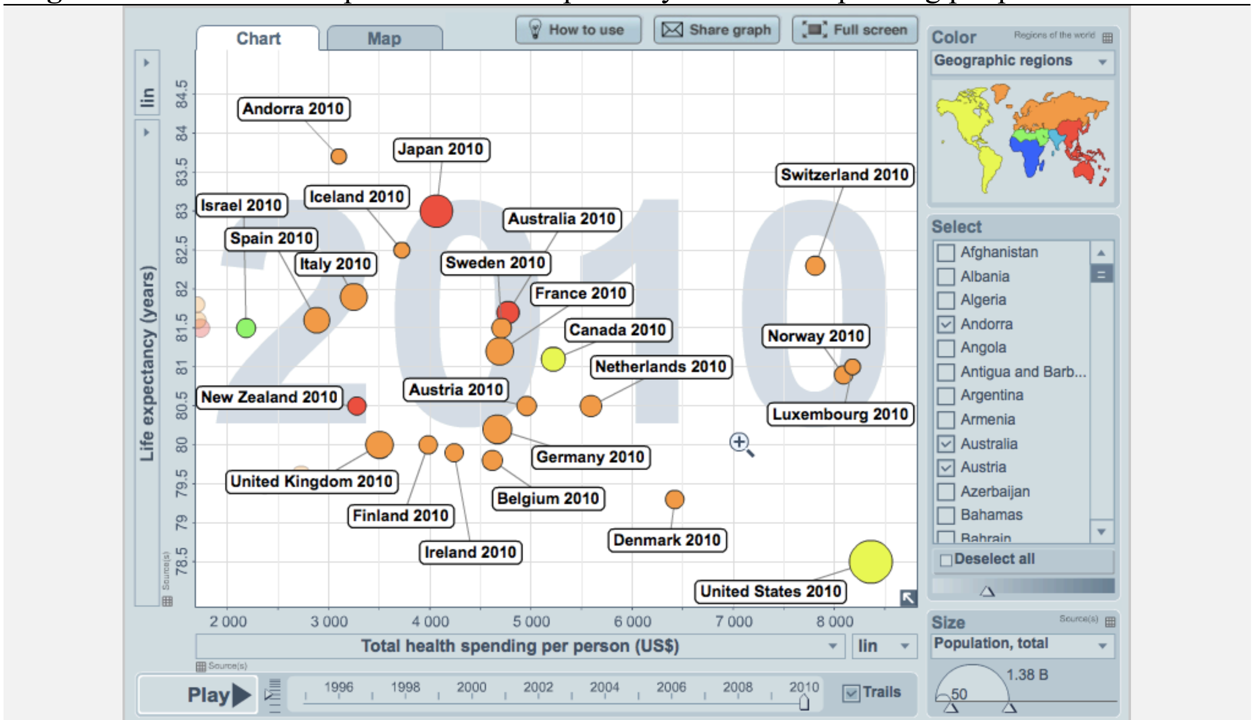

Figure 4: The relationship between child mortality and health spending per person[11].

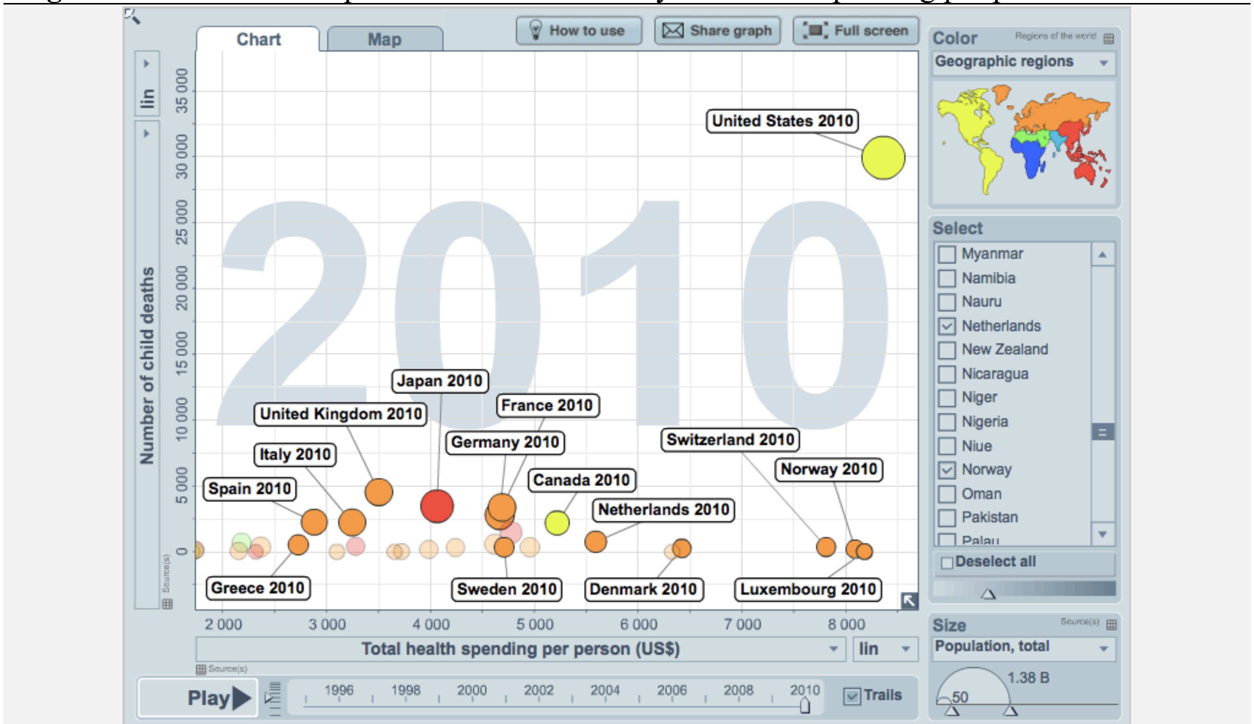

Table 1: Baseline patient characteristics.

Variable	n	%
Sex		
Female	38,171	71.2
Male	15,461	28.8
Age mean ± SD (range)	48.7 ± 15.6 (16-99)	
Age group, years		
< 25	3015	5.6
25 - < 35	8275	15.4
35 - < 45	11,400	21.3
45 - < 55	12,676	23.6
55 - < 65	10,678	19.9
65 - < 75	4,283	8.0
75+	3,305	6.2
Region of country		
Northeast	9,715	18.1
Midwest	8,906	16.6
South	27,439	51.2
West	7,528	14.0
Unknown	44	0.1
Type of surgery		
Laparoscopic	50,900	94.9
Open	2,161	4.0
Unknown/conversion*	571	1.1
Surgery visit type		
Outpatient	34,285	63.9
Inpatient	19,347	36.1

*Indicates that both laparoscopic and open procedures were coded in claims database.

Table 2: Prevalence of comorbidities in the study population.

Comorbidity	n	%
Hypertension	18,324	34.2
Hyperlipidemia	16,436	30.7
GERD / hiatal hernia	13,465	25.1
Diabetes mellitus	7,354	13.7
Angina / chronic IHD	4,065	7.6
Sleep apnea	3,064	5.7
Heart failure	1,217	2.3
MI / acute IHD	1,136	2.1
Hypertensive heart disease	1,061	2.0
Cirrhosis of liver or bile ducts	283	0.5

Table 3: 30-day health care utilization.

Visit Type	Number of Visits	Number of Patients	% of Cohort
ED visits	4,523	3,538	6.6
Inpatient readmissions		4,103	7.7
0 days		2,461	60.0
1-2 days		677	16.5
3-5 days		583	14.2
6-10 days		214	5.2
11+ days		168	4.1

Table 4: ICD-9 codes and corresponding diagnoses for 30-day readmissions.

ICD-9	Corresponding Diagnosis	n	%
789.00	Abdominal pain; unspecified site	700	7.6
786.50	Chest pain NOS*	223	2.4
789.01	Abdominal pain; right upper quadrant	217	2.4
997.4	Digestive system complications	212	2.3
574.50	Choledocholithiasis NOS	205	2.2
577.0	Acute pancreatitis	190	2.1
574.10	Calculus of gallbladder with other cholecystitis; without mention of obstruction	164	1.8
576.8	Other specified disorders of the biliary tract	152	1.7
789.07	Abdominal pain, generalized	146	1.6
787.01	Nausea with vomiting	145	1.6

*NOS: Not otherwise specified

Table 5: Univariate analysis of 30-day resource utilization stratified by sex.

	Female N=38,171		Male N=15,461		Chi Square
	n	%	n	%	*P* value
Visit to the ED	2,552	6.7	986	6.4	0.1925
30-day readmission	2,579	6.8	1,524	9.9	<.0001

Table 6: Univariate analysis of 30-day resource utilization stratified by comorbidity.

Heart Failure					
	(+) N=1,217		(-) N=52,415		Chi Square
	n	%	n	%	*P* value
Visit to the ED	131	10.8	3,407	6.5	<.0001
30-day readmission	348	28.6	3,755	7.2	<.0001
Angina / Chronic IHD					
	(+) N=4,065		(-) N=49,567		Chi Square
	n	%	n	%	*P* value
Visit to the ED	344	8.5	3,194	6.4	<.0001
30-day readmission	740	18.2	3,363	6.8	<.0001

	(+) N		(-) N		Chi Square
GERD / Hiatal Hernia					
	(+) N=13,465		**(-) N=40,167**		**Chi Square**
	n	**%**	**n**	**%**	***P* value**
Visit to the ED	1,009	7.5	2,529	6.3	<.0001
30-day readmission	1,103	8.2	3,000	7.5	0.7087
Myocardial Infarction / Acute IHD					
	(+) N=1,136		**(-) N=52,496**		**Chi Square**
	n	**%**	**n**	**%**	***P* value**
Visit to the ED	104	9.2	3,434	6.5	0.0004
30-day readmission	243	21.4	3,860	7.4	<.0001
Sleep Apnea					
	(+) N=3,064		**(-) N=50,568**		**Chi Square**
	n	**%**	**n**	**%**	***P* value**
Visit to the ED	249	8.1	3,289	6.5	0.0004
30-day readmission	293	9.6	3,810	7.5	0.7843
Diabetes Mellitus					
	(+) N=7,354		**(-) N=46,278**		**Chi Square**
	n	**%**	**n**	**%**	***P* value**
Visit to the ED	547	7.4	2,991	6.5	0.0018
30-day readmission	912	12.4	3,191	6.9	<.0001
Hypertension					
	(+) N=18,324		**(-) N=35,308**		**Chi Square**
	n	**%**	**n**	**%**	***P* value**
Visit to the ED	1,280	7.0	2,258	6.4	0.0090
30-day readmission	1,986	10.8	2,117	6.0	<.0001
Cirrhosis of the Liver or Bile Ducts					
	(+) N=283		**(-) N=53,349**		**Chi Square**
	n	**%**	**n**	**%**	***P* value**
Visit to the ED	28	9.9	3,510	6.6	0.0251
30-day readmission	43	15.2	4,060	7.6	0.1382
Hyperlipidemia					
	(+) N=16,436		**(-) N=37,196**		**Chi Square**
	n	**%**	**n**	**%**	***P* value**
Visit to the ED	1,040	6.3	2,498	6.7	0.0950
30-day readmission	1,551	9.4	2,552	6.9	0.0001
Hypertensive Heart Disease					
	(+) N=1,061		**(-) N=52,571**		**Chi Square**
	n	**%**	**n**	**%**	***P* value**
Visit to the ED	79	7.4	3,459	6.6	0.2605
30-day readmission	156	14.7	3,947	7.5	0.5003

Table 7: Multivariable odds ratios for 30-day readmissions.

Predictor	**Odds Ratio**	**95% Wald**	**Confidence Limits**	**Chi Square *P*-Value**
Female	0.885	0.823	0.950	0.0008
Region (Reference: Midwest):				

Northeast	0.905	0.811	1.010	<.0001
South	0.885	0.809	0.969	
West	0.969	0.862	1.090	
Age Group (Reference: 25-34)				
<25	1.347	1.131	1.605	<.0001
35-44	0.993	0.872	1.130	
45-54	1.061	0.935	1.204	
55-64	1.287	1.131	1.465	
65-74	2.003	1.730	2.317	
75+	4.277	3.717	4.922	
Baseline Comorbidities:				
Heart Failure	2.078	1.795	2.406	<.0001
Cirrhosis of Liver or Bile Ducts	1.640	1.164	2.312	0.0047
MI / Acute IHD	1.463	1.236	1.733	<.0001
Angina / Chronic IHD	1.300	1.162	1.454	<.0001
Diabetes	1.293	1.184	1.413	<.0001
Hypertensive Heart Disease	1.244	1.035	1.495	0.0201
Hypertension	1.188	1.097	1.287	<.0001
Hyperlipidemia	0.867	0.801	0.938	0.0004

Predictors that were not statistically significant: GERD and sleep apnea.

APPENDICES

Appendix 1: ICD-9 codes and CPT codes used to identify cholecystectomy procedures.

ICD-9
- 51.22 Cholecystectomy
- 51.23 Laparoscopic cholecystectomy

CPT
- 47600 Cholecystectomy
- 47610 Cholecystectomy with exploration of common duct
- 47605 Cholecystectomy; with cholangiography
- 47562 Laparoscopic cholecystectomy
- 47563 Laparoscopic cholecystectomy with cholangiography
- 47564 Laparoscopic cholecystectomy with exploration of common duct

Appendix 2: Detailed univariate analysis of 30-day resource utilization stratified by sex.

	Female N=38,171		**Male N=15,461**		**Chi Square**
	n	**%**	**n**	**%**	***P* value**
Visit to the ED	2,552	6.7	986	6.4	0.1925
Number of ED visits					
None	35,619	93.3	14,475	93.6	
1 visit	2,018	5.3	806	5.2	
2 visits	393	1.0	137	0.9	
3^+ visits	141	0.4	43	0.3	
30-day readmission	2,579	6.8	1,524	9.9	<.0001
Inpatient total LOS					
0 days	1,501	3.9	960	6.2	
1-2 days	469	1.2	208	1.3	
3-5 days	378	1.0	205	1.3	
6-10 days	132	0.3	82	0.5	
11^+ days	99	0.3	69	0.4	

Appendix 3: Detailed univariate analysis of 30-day resource utilization stratified by comorbidity.

Heart Failure	**(+) N=1,217**		**(-) N=52,415**		**Chi Square**
	n	**%**	**n**	**%**	***P* value**
Visit to the ED	131	10.8	3,407	6.5	<.0001
Number of ED visits					
None	1,086	89.2	49,008	93.5	
1 visit	92	7.6	2,732	5.2	
2 visits	22	1.8	508	1.0	
3^+ visits	17	1.4	167	0.3	

30-day readmission	348	28.6	3,755	7.2	<.0001
Inpatient total LOS					
0 days	256	21.0	2,205	4.2	
1-2 days	34	2.8	643	1.2	
3-5 days	24	2.0	559	1.1	
6-10 days	12	1.0	202	0.4	
11^{+} days	22	1.8	146	0.3	
Angina / Chronic IHD					
	(+) N=4,065		**(-) N=49,567**		**Chi Square**
	n	**%**	**n**	**%**	***P* value**
Visit to the ED	344	8.5	3,194	6.4	<.0001
Number of ED visits					
None	3,721	91.5	46,373	93.6	
1 visit	265	6.5	2,559	5.2	
2 visits	58	1.4	472	1.0	
3^{+} visits	21	0.5	163	0.3	
30-day readmission	740	18.2	3,363	6.8	<.0001
Inpatient total LOS					
0 days	540	13.3	1,921	3.9	
1-2 days	77	1.9	600	1.2	
3-5 days	58	1.4	525	1.1	
6-10 days	26	0.6	188	0.4	
11^{+} days	39	1.0	129	0.3	
GERD / Hiatal Hernia					
	(+) N=13,465		**(-) N=40,167**		**Chi Square**
	n	**%**	**n**	**%**	***P* value**
Visit to the ED	1,009	7.5	2,529	6.3	<.0001
Number of ED visits					
None	12,456	92.5	37,638	93.7	
1 visit	775	5.8	2,049	5.1	
2 visits	164	1.2	366	0.9	
3^{+} visits	70	0.5	114	0.3	
30-day readmission	1,103	8.2	3,000	7.5	0.7087
Inpatient total LOS					
0 days	676	5.0	1,785	4.4	
1-2 days	169	1.3	508	1.3	
3-5 days	153	1.1	430	1.1	
6-10 days	61	0.5	153	0.4	
11^{+} days	44	0.3	124	0.3	
MI / Acute IHD					
	(+) N=1,136		**(-) N=52,496**		**Chi Square**
	n	**%**	**n**	**%**	***P* value**
Visit to the ED	104	9.2	3,434	6.5	0.0004
Number of ED visits					
None	1,032	90.8	49,062	93.5	
1 visit	80	7.0	2,744	5.2	

2 visits	17	1.5	513	1.0	
3^+ visits	7	0.6	177	0.3	
30-day readmission	243	21.4	3,860	7.4	<.0001
Inpatient total LOS					
0 days	181	15.9	2,280	4.3	
1-2 days	22	1.9	655	1.2	
3-5 days	21	1.8	562	1.1	
6-10 days	10	0.9	204	0.4	
11^+ days	9	0.8	159	0.3	
Sleep Apnea					
	(+) N=3,064		**(-) N=50,568**		**Chi Square**
	n	**%**	**n**	**%**	***P* value**
Visit to the ED	249	8.1	3,289	6.5	0.0004
Number of ED visits					
None	2,815	91.9	47,279	93.5	
1 visit	197	6.4	2,627	5.2	
2 visits	34	1.1	496	1.0	
3^+ visits	18	0.6	166	0.3	
30-day readmission	293	9.6	3,810	7.5	0.7843
Inpatient total LOS					
0 days	179	5.8	2,282	4.5	
1-2 days	53	1.7	624	1.2	
3-5 days	36	1.2	547	1.1	
6-10 days	13	0.4	201	0.4	
11^+ days	12	0.4	156	0.3	
Diabetes Mellitus					
	(+) N=7,354		**(-) N=46,278**		**Chi Square**
	n	**%**	**n**	**%**	***P* value**
Visit to the ED	547	7.4	2,991	6.5	0.0018
Number of ED visits					
None	6,807	92.6	43,287	93.5	
1 visit	431	5.9	2,393	5.2	
2 visits	77	1.0	453	1.0	
3^+ visits	39	0.5	145	0.3	
30-day readmission	912	12.4	3,191	6.9	<.0001
Inpatient total LOS					
0 days	577	7.8	1,884	4.1	
1-2 days	130	1.8	547	1.2	
3-5 days	116	1.6	467	1.0	
6-10 days	47	0.6	167	0.4	
11^+ days	42	0.6	126	0.3	
Hypertension					
	(+) N=18,324		**(-) N=35,308**		**Chi Square**
	n	**%**	**n**	**%**	***P* value**
Visit to the ED	1,280	7.0	2,258	6.4	0.0090
Number of ED visits					

None	17,044	93.0	33,050	93.6	
1 visit	1,012	5.5	1,812	5.1	
2 visits	181	1.0	349	1.0	
3+ visits	87	0.5	97	0.3	
30-day readmission	1,986	10.8	2,117	6.0	<.0001
Inpatient total LOS					
0 days	1,283	7.0	1,178	3.3	
1-2 days	413	2.3	413	1.2	
3-5 days	335	1.8	335	0.9	
6-10 days	117	0.6	117	0.3	
11+ days	74	0.4	74	0.2	
Cirrhosis of the Liver or Bile Ducts					
	(+) N=283		**(-) N=53,349**		**Chi Square**
	n	**%**	**n**	**%**	***P* value**
Visit to the ED	28	9.9	3,510	6.6	0.0251
Number of ED visits					
None	255	90.1	49,839	93.4	
1 visit	19	6.7	2,805	5.3	
2 visits	7	2.5	523	1.0	
3+ visits	2	0.7	182	0.3	
30-day readmission	43	15.2	4,060	7.6	0.1382
Inpatient total LOS					
0 days	27	9.5	2,434	4.6	
1-2 days	3	1.1	674	1.3	
3-5 days	5	1.8	578	1.1	
6-10 days	5	1.8	209	0.4	
11+ days	3	1.1	165	0.3	
Hyperlipidemia					
	(+) N=16,436		**(-) N=37,196**		**Chi Square**
	n	**%**	**n**	**%**	***P* value**
Visit to the ED	1,040	6.3	2,498	6.7	0.0950
Number of ED visits					
None	15,396	93.7	34,698	93.3	
1 visit	836	5.1	1,988	5.3	
2 visits	150	0.9	380	1.0	
3+ visits	54	0.3	130	0.3	
30-day readmission	1,551	9.4	2,552	6.9	0.0001
Inpatient total LOS					
0 days	1,001	6.1	1,460	3.9	
1-2 days	218	1.3	459	1.2	
3-5 days	193	1.2	390	1.0	
6-10 days	78	0.5	136	0.4	
11+ days	61	0.4	107	0.3	
Hypertensive Heart Disease					
	(+) N=1,061		**(-) N=52,571**		**Chi Square**
	n	**%**	**n**	**%**	***P* value**

Visit to the ED	79	7.4	3,459	6.6	0.2605
Number of ED visits					
None	982	92.6	49,112	93.4	
1 visit	61	5.7	2,763	5.3	
2 visits	15	1.4	515	1.0	
3^{+} visits	3	0.3	181	0.3	
30-day readmission	156	14.7	3,947	7.5	0.5003
Inpatient total LOS					
0 days	94	8.9	2,367	4.5	
1-2 days	22	2.1	655	1.2	
3-5 days	20	1.9	563	1.1	
6-10 days	10	0.9	204	0.4	
11^{+} days	10	0.9	158	0.3	

Appendix 4: Multivariable odds ratios for 30-day readmissions with same-day discharge.

Predictor	**Odds Ratio**	**95% Wald Confidence Limits**		**Chi Square *P*-Value**
Age Group (Reference: 25-34 years)				<.0001
<25	1.405	1.102	1.792	
35-44	1.012	0.843	1.216	
45-54	1.130	0.947	1.349	
55-64	1.420	1.188	1.698	
65-74	3.192	2.646	3.850	
75+	7.772	6.498	9.297	
Baseline Comorbidities:				
Angina / Chronic IHD	1.363	1.197	1.553	<.0001
Cirrhosis of the Liver or Bile Ducts	1.634	1.066	2.504	0.0241
Diabetes	1.226	1.099	1.368	0.0003
Heart Failure	1.964	1.662	2.322	<.0001
Hyperlipidemia	0.884	0.801	0.975	0.0138
Hypertension	1.122	1.013	1.242	0.0269
MI / Acute IHD	1.564	1.290	1.897	<.0001

Predictors that were not significant: Sex, region, GERD, sleep apnea, hypertensive heart disease

Appendix 5: Multivariable odds ratios for 30-day overnight readmissions.

Predictor	**Odds Ratio**	**95% Wald Confidence Limits**		**Chi Square *P*-Value**
Female	0.854	0.767	0.951	0.0040
Region (Reference: Midwest):				
Northeast	0.963	0.820	1.131	0.0056
South	0.819	0.715	0.937	

West	0.968	0.814	1.151	
Baseline Comorbidities:				
Angina / Chronic IHD	1.207	1.012	1.439	0.0360
Diabetes	1.377	1.201	1.579	<.0001
Heart Failure	1.874	1.475	2.381	<.0001
Hyperlipidemia	0.863	0.766	0.973	0.0163
Hypertension	1.271	1.131	1.428	<.0001
Hypertensive Heart Disease	1.580	1.207	2.069	0.0009

Predictors that were not statistically significant: Age, GERD, sleep apnea, acute IHD, and cirrhosis of the liver or bile ducts.